Terahertz biometric sensors for fingerprint scanning

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***Abstract*— This study is motivated by a combination of the sustainability and vital need for enhancing authentication security of digital devices, both personal and corporate. We present an in-house built millimeter-wave frequency biometric sensor setup and obtained original data, measured in real-time, of both an artificial stamp and a real human fingerprint. This setup lays the ground for an intended biometric sensor for further use implementing graphene, which is foreseen to be an important two-dimensional material in future electronics and sensing applications.**

I. Introduction

THE terahertz radiation consists of electromagnetic waves within the band of frequencies from 0.1 to 30 terahertz (THz). Unlike X-rays, terahertz radiation is not ionizing and does not damage live tissues and DNA. The terahertz waves can penetrate the drier outer skin layers and provide anatomical information on the underlying/subcutaneous structures that cannot be duplicated as easily as artificial fake fingerprints [1-2]. Therefore, terahertz imaging can serve as a novel method of advanced fingerprint identification, and other biometric authentications, with significantly higher security levels.

In this study, we have used an in-house built real-time and high-resolution terahertz fingerprint imaging setup. To build this setup, schematically depicted in Fig. 1, simulations were done in *Optical Ray Tracer*, providing the required parameter values, presented in Fig. 2.

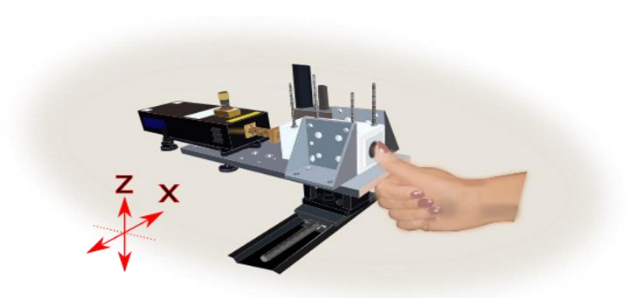
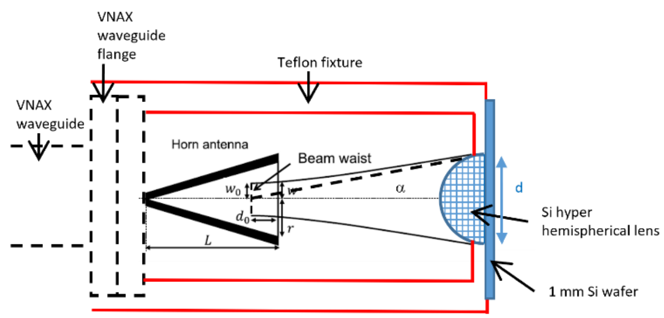


Fig. 1. a) Schematic of experimental set-up for scanning fingerprint using THz frequency and indicating the placement of graphene sensor.

The various components are marked in Fig. 2, first, the VNAX waveguide, then the VNAX waveguide flange, followed by a horn antenna. The antenna length (L), antenna radius (r), beam waist (W_0), beam depth (d_0), and angle (α) to the Si hyper hemispherical lens and its diameter (d) are all indicated in the figure. The antenna and beam part is shielded with a Teflon fixture, and the lens is placed right behind a 1 mm thick Si wafer. The experimental setup, where the VNAX, a horn antenna, and a Si-lens module are seen, is shown in Fig. 3.



λ	D	α	R	d
1 mm	5.6 mm	5 deg (3 dB)	>63 mm	>11 mm

Fig. 2. Schematic image of set-up, with indicated geometry parameters such as:

Fig. 3. A step-by-step illustration of building the set-up.

The setup was successful initially, but sampling quality data met a few challenges before it could be considered useful. The main challenges faced were resolution, reproducibility, and stability. The challenges were addressed at a time and could be solved by additional modifications to the setup. The resolution could be solved with the software and proper calibration. Reproducibility could be confirmed by fabricating a test structure of an artificial test valley and investigating the profile, with a size in the same range as a feature in a fingerprint structure. The stability issues were apparent when several sweeps were repeated and the object, or finger, was not fixed,

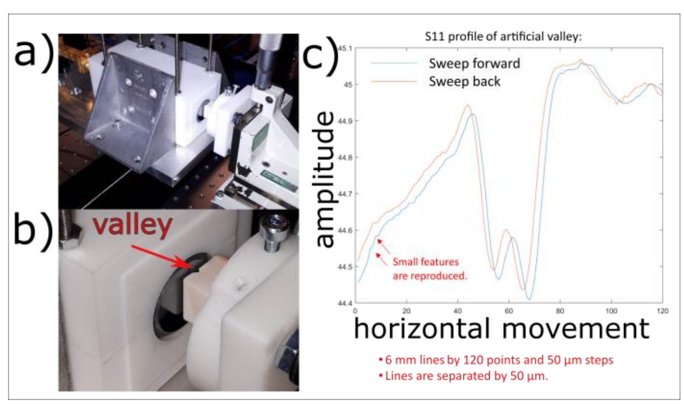


Fig. 4. a) Picture of experimental set-up for investigation reproducibility b) S11 profile of artificial valley.

resulting in a drifting pattern not accurate to reality. The stability issue could easily be solved by fabricating a holder to place in front of the detection surface and mounting the whole set-up on a stepper, adjustable in both x and y-led, where speed, scanning pattern, and step size could be controlled via a computer script.

The setup was based on a commercial terahertz transceiver in the WR3.4 band (220-330 GHz) coupled with a vector network analyzer (VNA). The built prototype is demonstrated in Fig. 4, with the profile of the artificial test valley detecting small features, repeatable in both forward and backward scans.

The reflected terahertz spectra images were then synthesized by raster scanning the surface of a finger via a mechanical translation stage. The acquired images of the reflected terahertz signals are the first of their kind and are presented in the following section.

II. Results

In the first attempt to scan a fingerprint, an artificial stamp was used. The stamp was produced using play-do clay for shaping a mold and wood glue to create the stamp itself, as shown in Fig. 5 a)-c). The edge of the stamp was scanned to facilitate the scanning coordinates and evaluate the resolution of the amplitude. In Fig. 5 d), an image taken using an optical

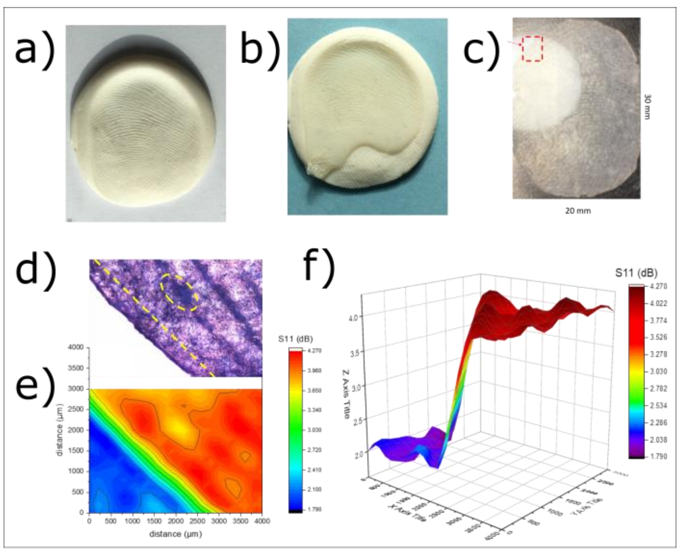


Fig. 5. a) artificial fingerprint created with b) play-do and wooden glue. c) Optical microscope of artificial fingerprint edge and d) the first scan of artificial fingerprint edge. d) height profile of the same scanned area.

microscope is presented, and below in Fig. 5 e), the same area is scanned using the built setup. It is clear from Fig d)-f) We could reproduce the artificial fingerprint and detect small features like the valleys and ridges in the stamp. Fig. 5 f) also show the amplitude of the measures area, which correlates well with features in the stamp and edge of the stamp.

After the successful attempt of scanning a stamp, the next challenge would be to scan a real finger. Fig. 6 presents our preliminary data from such measurements. The raw data is presented in 3D from three different perspectives, and ridges of the fingerprint can be observed, where a guide for the eye is added in a blurred red shadow.

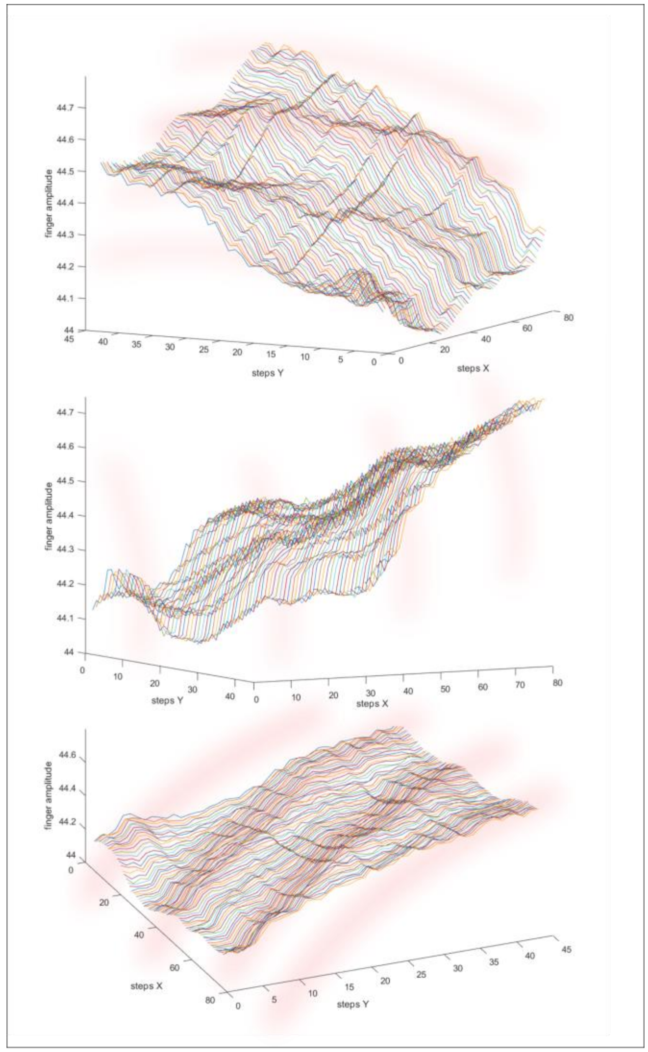


Fig. 6. Scan of real fingerprint section, with three angles of the same 3D plot.

In conclusion, a successful fingerprint scanner was built utilizing the bio-safe THz frequency range to detect small features in real fingerprints. Generally, the presented methodology can be used in various advanced and emerging authentication applications, e.g., door locks, facial recognition, etc.

Acknowledgments

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References

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